URANIUM LEVELS IN WATER IN EVAPORATION BASINS USED FOR THE DISPOSAL OF AGRICULTURAL SUBSURFACE DRAINAGE WATER IN THE SAN JOAQUIN VALLEY, CALIFORNIA

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EXECUTIVE SUMMARY

Between 1985 and 1988, Regional Board staff conducted four water and sediment quality surveys of the 27 existing evaporation basins used for disposal of subsurface agricultural drainage water, 24 of which are in the Tulare Basin. During a screening of water samples for trace elements, elevated levels of uranium were detected in one of the basins. A similar detection of uranium was made by the U. S. Geological Survey in a water sample from another basin. These findings raised the concern that uranium may be present at high concentrations in the final evaporation cells of the basins. An appraisal was initiated to document the uranium concentrations in the water samples collected from each cell and inlet of the existing evaporation basins. The samples collected in the 1987 and 1988 basin surveys were used for analysis.

The inflow uranium concentrations varied between 24 and 1,200 ug/L however like the trace elements selenium, molybdenum and arsenic, the inflow concentration showed a relationship with geologic setting. The mean inflow uranium concentration for basins on the lake-bed deposits was 560 ug/L as compared to 115 and 120 ug/L for the inlets to basins on the basin-trough and alluvial fan deposits, respectively. The lowest uranium concentrations were found in the inflow to the evaporation basins near the northern edge of the Tulare Lake Bed while the highest concentrations were found in inflow to the basins in the area from the southern Tulare Lake Bed south to the Goose Lake Bed area. The highest inflow concentration was found at 1,200 ug/L in the Alpaugh area of Tulare County.

The elevated concentrations in the inlet samples translated into elevated levels in the evaporation basins. As a result, only 4 basins sampled had uranium concentrations less than 100 ug/L and these basins represent less than 10 percent of the surface acreage. The most recent criterion available for protection of wildlife is that used by the Canadian Government for salt water of 500 ug/L. A full review of this criterion is needed as this water quality survey shows that as much as 60 percent of the ponded acreage approaches or exceeds the 500 ug/L protection criterion. Almost 50 percent of the samples collected from the basins had uranium concentrations greater than 400 ug/L. Of these elevated samples, 45 percent had uranium concentrations in excess of 1,000 ug/L; twice the recommended protection criterion.

The data for molybdenum from our previous study show a similar high concentration in a majority of the ponded acreage. Both molybdenum and uranium are highly mobile under alkaline conditions and both showed strongly elevated concentrations in basins on the lake-bed deposits and were found to be in association with each other in three basins in the Tulare Lake area.

A preliminary review of the criterion for uranium for wildlife is in progress. In addition, the presence of uranium at such high concentrations might indicate the presence of high levels of the much more hazardous radium isotopes. A full evaluation of the presence of radium and its isotopes has been recommended.

I. BACKGROUND

Between 1985 and 1988, Regional Board staff conducted four water and sediment quality surveys of the 27 existing evaporation basins used for disposal of subsurface agricultural drainage water. Basins in the San Joaquin Valley are located from the Bakersfield area in the south to near Gustine in the north. These facilities cover 7,160 acres (2,900 hectares) with basin sizes ranging from 10 to 1,800 acres (5 to 730 hectares). Water quality samples for total selenium, selected trace elements and minerals were taken from each of the 89 individual basin cells and 53 basin inlets that contained water at the time of the surveys. Sediment samples were taken from the upper 7 cm layer of each basin cell bottom that contained or had contained subsurface drainage water. Sediment samples were analyzed for selected trace elements including selenium. Results of this water and sediment survey are presented in Westcot et al.(1988) and Westcot, 1988.

Trace element concentrations measured during these surveys varied widely, but did show that future monitoring efforts should be directed at four trace elements; selenium, molybdenum, arsenic and boron. Each of these elements occurred in high concentrations in one or more of the basins. Evaporation basin concentrations reflected inflow quality and the degree of evapoconcentration. In those basin cells operated "in-series", where final evaporation takes place in the last cells, the influence of evapoconcentration was strong. Only one basin exceeded the hazardous waste levels defined in the California Code of Regulations(CCR) and only one sample from another basin exceeded the hazardous waste level defined for total arsenic. However subsequent sampling at this site was not able to confirm the original high arsenic level.

Inflow trace element concentrations, although varying widely between sites appeared to show a relationship with the geologic setting of the basin. For example, inlets to basins in alluvial fan areas showed a geometric mean selenium concentration of 300 ug/L, as compared to 2 and 12 ug/L for inlets to the basins located on the basin-trough and lake-bed deposits, respectively. Molybdenum and arsenic concentrations in the inlet samples also showed a strong relationship to the geologic setting. However in contrast to selenium, the highest concentrations were found in inflow samples from basins on lake-bed deposits. Consistently high arsenic concentrations were associated with inflow samples for basins in the southern half of the Tulare Lake Bed, while the highest molybdenum concentrations were associated with basin inflows in the Goose Lake Bed area. Boron concentrations did not show a definite relationship to geologic setting.

The available data indicate that cadmium, chromium, copper, lead, mercury, nickel and zinc, if present, were at relatively low concentrations in the evaporation basins. In no instance did these concentrations exceed the hazardous waste levels defined in the California Code of Regulations or the potential designated waste levels in assessing regulation under Subchapter 15 of the California Code of Regulations.

Considerable difficulty has been encountered in the analysis of these highly concentrated samples from the evaporation basins. The major difficulty appears to be the strong interference encountered from the very high salt matrix, especially from the sulfate ion in the evaporation basin samples. Sulfate in many samples makes up 75 percent or greater of the anions present. Total dissolved solids content in the samples are often 5 to 12 times that of seawater. As a result, the Regional Board has initiated a specialized laboratory study to assess selected methodologies to overcome the interferences and allow low level detection of certain trace elements. In addition this Regional Board study is looking at the existence of other trace elements that may be of concern in the operation or regulation of the basins.

During an initial screening of trace elements as part of this study, chemists at the University of California, Riverside detected elevated levels of uranium in samples from one of the evaporation basins(Gordon Bradford, 1988, personal communication). A similar detection of uranium was made by the U. S. Geological Survey in another evaporation basin in the San Joaquin Valley(Schroeder et al., 1988). Because of the ability of uranium to form soluble complexes, the findings of elevated concentrations in two evaporation basins raises the concern that uranium may be present at higher concentrations in the final evaporation cells of the basins. Because the presence of radiometric constituents in the water of these basins presents an unknown hazard to wildlife and/or groundwater resources, a further appraisal was needed. Initial efforts were directed at documenting the baseline uranium concentrations in each cell and inlet of the existing evaporation basins. This data would be used to establish priorities for discharger monitoring and regulatory programs including the need for increased regulatory work regarding Subchapter 15 of the California Code of Regulations(CCR), Title 23, Sections 2510-2601 and the Hazardous Waste Criteria found in Title 22, CCR, Section 66699 as it applies to the Toxic Pits Cleanup Act (TPCA).

This report covers the work done by staff to characterize and define the present concentrations of uranium in the water found in the evaporation basins. The field and laboratory methods used are described along with a discussion of existing uranium concentrations in the basins. A description of the basin locations and environment including the geologic setting upon which the basins are located are described in detail in Westcot et al.(1988) and will not be repeated here.

II. FIELD SURVEYS AND DATA COLLECTION

Inspections of each basin were conducted June 1985, 1-3 December 1986, 8-11 June 1987 and 7-8 June 1988. Not all basins or inlets were accessible or contained water during each survey period. Only the data from the two most recent (1987 and 1988) surveys were used for this special uranium study. Figure 1 shows the location of the evaporation basins within the Tulare Lake Basin. The majority of these basins were sampled in this special uranium survey.

A water quality sample was taken from each cell or subcell within an evaporation basin during each inspection. A similar sample was taken from each inlet to the basin. All samples were taken in washed and acid-rinsed polyethylene bottles. All sample bottles were rinsed three times with the basin water prior to sampling. All unfiltered uranium samples were preserved to a pH of less than 2.0 using ultra-pure nitric acid fixation techniques. All uranium samples were kept at approximately the basin water temperature prior to fixation with nitric acid. This avoided precipitation in these highly concentrated samples that might be caused by lower than ambient temperatures. All uranium samples were fixed with nitric acid within 4 hours of the time the actual sample was taken from the basin or inlet.

A quality control and quality assurance program was conducted. For uranium analysis, spike and duplicate samples were utilized in the laboratory. In addition, 10 percent blind duplicate samples were submitted to the laboratory with 50 percent of these being spiked with known concentrations in the range of those expected in the samples. Internal standards were used in the laboratory. Reported results in this report all fall within the quality assurance tolerance guidelines for water analysis.

III. RESULTS OF WATER QUALITY ANALYSES

A summary of the uranium concentrations in water samples collected at evaporation basin sites by Regional Board staff for both inlet and basin cell water quality analyses is given in Table 1. It must be recognized that the results presented here are for grab samples collected in each basin or inlet and do not reflect the daily or seasonal variability within each basin cell or inlet.

Table 1. Concentration Ranges for Selected Constituents in Agricultural Subsurface Drainage Water Inlets and Evaporation Basins in the San Joaquin Valley. (Data for Total Dissolved Solids, Molybdenum, and Selenium taken from Westcot, et al, 1988).

	EVAPORATION BASINS				INLETS			
Constituent (Total Recoverable)	Minimum	Median	Geometric Mean	Maximum	Minimum	Median	Geometric Mean	Maximum
TDS (mg/L)	2,675	33,300	31,850	388,000	1,200	17,000	15,300	51,350
Mo (µg/L)	58	1,002	1,048	39,900	7	533	510	7,775
Se (µg/L)	0.2	14	17	1,940	< 1	10	11	943
U (µg/L)	30	430	340	11,000	24	140	175	1,200

Table 2. Selected Trace Element and Total Dissolved Solids Concentrations for Inlet Flow and Evaporation Basins as Influenced by Geologic Setting within the San Joaquin Valley.*
(Total dissolved solids, selenium, and molybdenum data taken from Westcot, et al, 1988.)

	INLET DATA				EVAPORATION BASIN DATA			
GEOLOGIC SETTING	TDS geometric mean mg/L (range)	Se geometric mean µg/L (range)	Mo geometric mean µg/L (range)	U geometric mean µg/L (range)	TDS geometric mean mg/L (range)	Se geometric mean µg/L (range)	Mo geometric mean µg/L (range)	U geometric mean µg/L (range)
Alluvial Fan	10,000 (1,150 - 46,400)	300 (72 - 943)	200 (40 - 1,665)	120 (64 - 170)	27,300 (10,800 - 130,000)	330 (2.1 - 1,940)	840 (58 - 13,250)	270 (57 - 2,200)
Basin Trough	12,600 (1,200 - 51,350)	2 (<1 - 32)	320 (7 - 1,050)	100 (24 - 280)	25,000 (1,800 - 163,500)	2 (0.2 - 10)	610 (150 - 2,165)	125 (30 - 530)
Lake Bed	16,500 (3,450 - 47,550)	12 (1.6 - 76)	1,240 (169 - 7775)	430 (70 - 1,200)	27,900 (4,200 - 388,000)	8 (1.1 - 62)	1,435 (165 - 39900)	460 (60 - 11,000)

* All water values reported as total recoverable.

Regional Board staff collected a total of 49 water quality samples from inlets to the evaporation basins during the two surveys. The mean uranium concentration for the inlet samples was 280 ug/L with a median concentration of 140 ug/L. The geometric mean for the inlet samples was 175 ug/L. The range of uranium concentration in the inlet samples was 24 to 1,200 ug/L. Inflow uranium concentrations, although varying widely between sites appeared, like selenium, molybdenum and arsenic (Westcot et al., 1988), to show a relationship with geologic setting (Figure 2). For uranium, inlets located in the lake-bed deposits had the highest concentrations measured in the inflow streams (Table 2). The mean inflow uranium concentration for basins on the lake-bed deposits was 560 ug/L as compared to 115 and 120 ug/L for the inlets to basins located on the basin-trough and alluvial fan deposits, respectively.

The lowest uranium concentrations were found in the inflow to the evaporation basins located near the northern edge of the Tulare Lake Bed while the highest concentrations were found in inflow to the basins in the area from the southern Tulare Lake Bed south to the Goose Lake Bed area. The highest inflow concentration was found at 1,200 ug/L in the Alpaugh area of Tulare County.

Uranium concentrations found in the basins varied widely but were higher than the respective inflow samples due to evaporative concentration. For example, the uranium concentrations for the basin samples ranged from 30 to 11,000 ug/L. The large variability is partly due to extensive evapoconcentration in certain basin cells, especially those basins that are operated "in-series" where final evaporation takes place in the last evaporation cells. The mean concentration for all the basin samples was approximately 675 ug/L in comparison to 280 ug/L uranium for the inflow samples to these basins. The influence of the geologic setting also could be seen in the basin concentrations with the mean concentration for the basins located on the lake-bed deposits being 950 ug/L while mean uranium concentrations of 190 and 400 ug/L were found in basins on the basin-trough and alluvial fan deposits, respectively. Table 2 shows the geometric mean uranium concentration for the basins in the different geologic settings. The geometric means were considerably lower than the mean values for the same data set indicating a wide variability in concentration in the samples collected.

The distribution of high and low uranium concentrations in the basins was directly related to the uranium concentration found in the basin inlet. Ranges of uranium and selected trace element concentrations in the basins are shown in Table 3. Only 27 percent of the basin inlet samples collected showed uranium concentrations less than 100 ug/L (Figure 3). Almost 30 percent of the inlet samples collected showed uranium concentrations in excess of 400 ug/L. This trend was similar to that found for the trace element molybdenum (Westcot et al., 1988); also a highly mobile ion under alkaline conditions. As a result only 4 basins sampled had uranium concentrations less than 100 ug/L and these basins represent less than 10 percent of the surface acreage of the twenty evaporation basins sampled during this survey. It is not expected that this percentage would change greatly with data from the

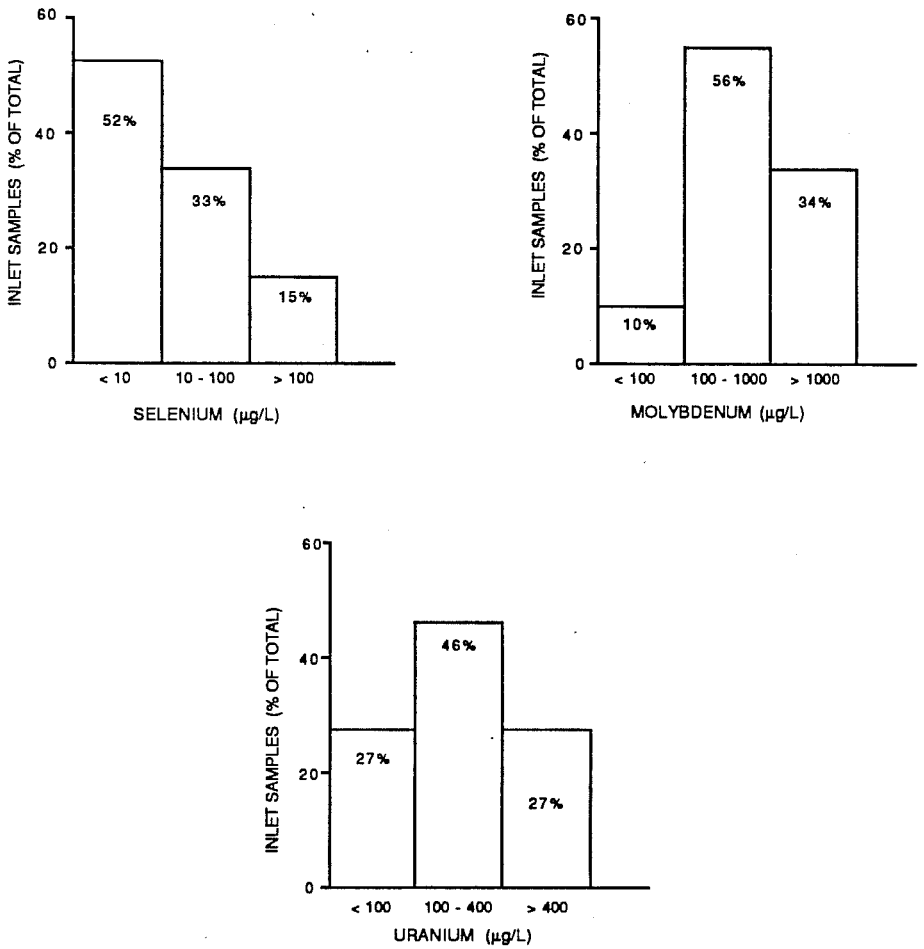
Table 3. 1987-1988 Ranges of Selected Constiuents in Drainage Water Evaporation Basins in the San Joaquin Valley, California **

Basins	Total Dissolved Solids (mg/L)	Arsenic (ug/L)	Molybdenum (ug/L)	Selenium (ug/L)	Uranium (ug/L)
1 Souza	ND	ND	ND	ND	ND
2 Lindemann	ND	ND	ND	ND	ND
3 Britz, South Dos Palos	1,300 - 5,800	ND	150 - 330	1.4 - 6.6	ND
4 Sumner Peck	11,000 - 48,000	3 - 5	84 - 420	470 - 2,210	130 - 720
5 Britz-Deavenport Five Points	18,300 - 24,300	5 - 10	270 - 390	35 - 79	57 - 63
6 Stone Land Co.	22,000 - 160,000	12 - 41	320 - 1,000	1 - 4.8	41 - 220
7 Carlton Duty	171,000 - 210,000	200	460 - 870	13 - 15	320 - 530
8 Westlake 1 & 2 (North)	26,700 - 110,000	20 - 26	440 - 1840	0.4 - 2.1	180 - 480
9 Meyers Ranch	12,000 - 25,900	8 - 13	270 - 700	0.2 - 0.5	30 - 82
10 Barbizon Farms	16,000 - 31,000	26 - 33	220 - 870	0.3 - 1.5	200 - 260
11 TLDD North	3,800 - 18,000	160 - 360	160 - 580	1.1 - 2.5	60 - 200
12 Westlake 3 (South)	16,700 - 98,000	10 - 52	310 - 680	3.1 - 8.6	93 - 290
13 Liberty Farms (J & W Farms)	ND	ND	ND	ND	ND
14 Pryse Farms	48,000 - 185,000	630 - 1200	2,740 - 6,380	9.4 - 16	570 - 1,500
15 Bowman Farms	41,000 - 80,000	66 - 80	3,150 - 6,470	13 - 33	400 - 790
16 Morris Farms	42,000 - 53,800	100	3,570 - 5,250	23 - 44	460 - 1,200
17 Martin Farms	32,000 - 78,400	240	4,350 - 10,100	37 - 51	910 - 1,900
18 Smith Farms	ND	ND	ND	ND	ND
19 Four - J Corp.	58,000 - 65,800	2,500	4,080 - 5,600	50 - 53	2,400 - 2,500
20 Nickell	ND	ND	ND	ND	ND
21 TLDD Hacienda Ranch	8,320 - 130,000	100 - 490	910 - 5,860	12 - 41	370 - 2,600
22 TLDD South	13,600 - 140,000	120 - 360	1,170 - 5,930	8.7 - 23	370 - 3,100
23 Lost Hills (Westfarmers)	11,800 - 110,000	10 - 18	1,360 - 3,480	130 - 600	180 - 480
24 Carmel Ranch (Willow Creek)	13,600 - 388,000	360 - 13,000	1,880 - 39,900	2.1 - 5.4	600 - 11,000
25 Lost Hills Ranch	15,300 - 40,400	820 - 960	2,820 - 6,980	2.6 - 3.8	200 - 470
26 Rainbow Ranch (Sam Andrews)	25,400 - 160,000	4 - 13	1,830 - 12,300	239 - 1,200	340 - 2,200
27 Chevron Land Co.	ND	ND	ND	ND	ND

** All values reported as total recoverable.

TLDD Tulare Lake Drainage District.
ND No data.

Fig. 3. Percentage of inlet samples collected showing selected selenium, molybdenum, and uranium concentrations (Se and Mo data taken from Westcot, et al, 1988).



remaining basins as the remaining seven basins represent only 10 percent of the total ponded acreage and are scattered throughout the sampling area. Almost 50 percent of the samples collected from the basins had uranium concentrations greater than 400 ug/L. Of these elevated samples, 45 percent had uranium concentrations in excess of 1,000 ug/L. As a result over 60 percent of the surface acreage of the twenty evaporation basins sampled during this survey had total recoverable uranium concentrations in excess of 400 ug/L.

Figure 4 shows the percentage of the total basin acreage showing selected uranium concentrations. Also shown in Figure 4 is data for molybdenum which shows a similar high concentration in a majority of the ponded acreage (Westcot et al., 1988). Both the molybdenum and uranium ions are known to have highly soluble forms under alkaline conditions. Alkaline conditions predominate in the inflow and water in the evaporation basins.

Fig. 4. Uranium concentrations found in evaporation basins for which data is available and the percentage of the total basin acreage sampled showing selected uranium and molybdenum concentrations.

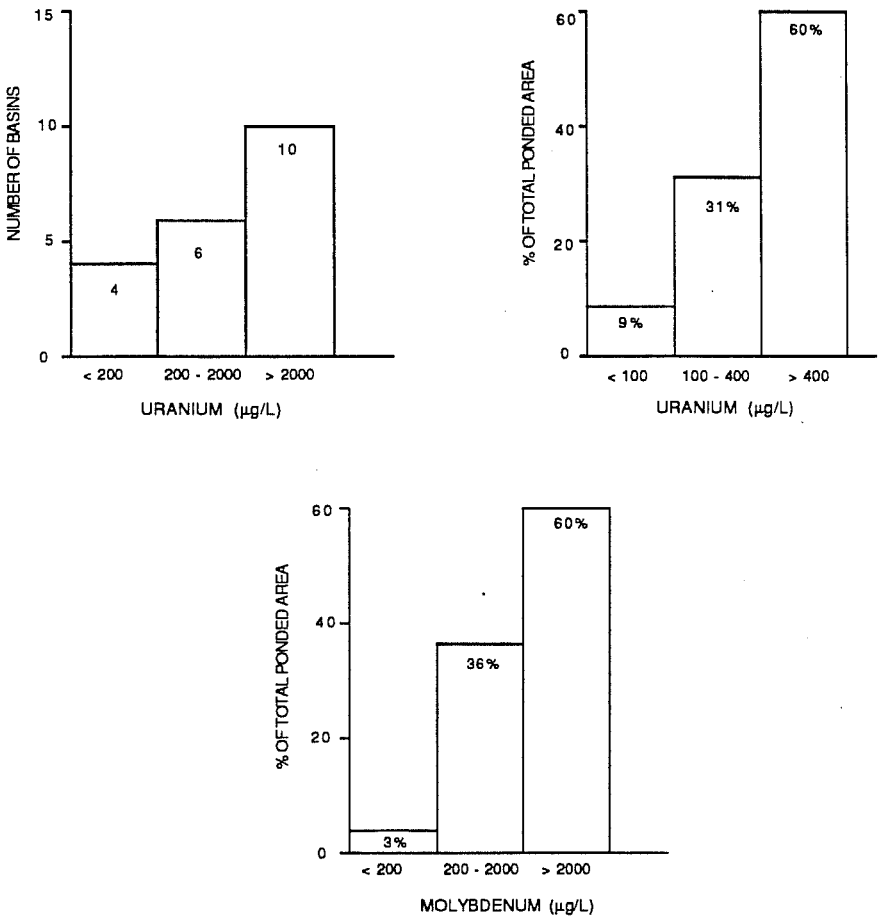
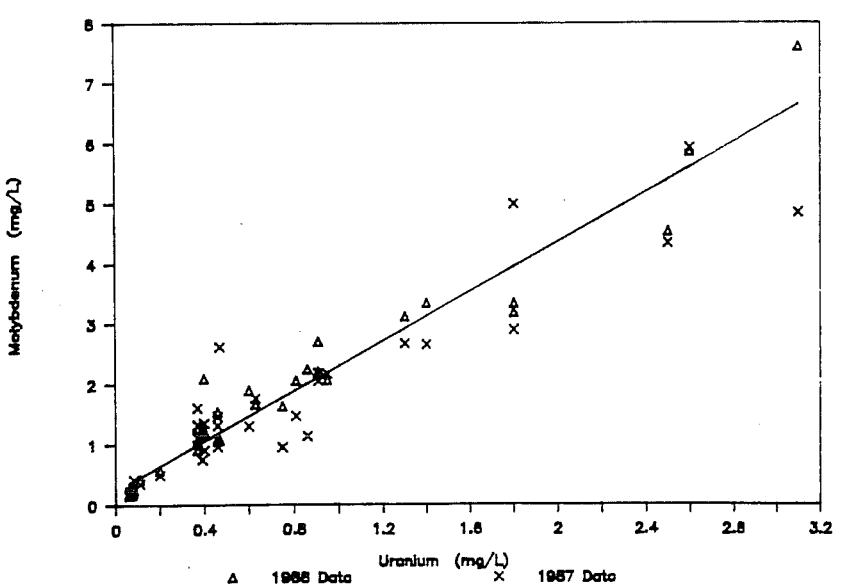


Fig. 5. Uranium concentrations associated with molybdenum concentrations for Evaporation Basins 11, 21, and 22 in 1987 and 1988 ($r^2 = 0.94$).



A general trend of increased concentration with continued evaporation has been observed in trace element data for boron, arsenic, molybdenum and selenium (Westcot et al., 1988). Evaporation basins operated "in-series" generally display a linear increase in concentration with increasing salinity when concentrations of the trace element are elevated. As both molybdenum and uranium are highly mobile under alkaline conditions and showed similar trends in elevated levels in the basins (Figure 4), a comparison was made to identify if an association exists between the two trace elements. Data for this analysis was taken from these basins on the lake-bed deposits as these showed elevated concentration of both elements (Table 2). A good relationship was found when these three basins in the Tulare Lake area were used (Figure 5). Although only a preliminary analysis, this shows that molybdenum and uranium are likely to be found in association with each other and as the concentration of one rises, the other is likely to rise. Data is not sufficient at present to test this relationship for each of the individual basins.

Few water quality criteria are available for uranium in either fresh or salt water. The State of Utah has adopted a water standard for uranium activity in water which is expressed as gross alpha radiation. The Utah standard for freshwater is 15 picocuries per liter and is for both human and aquatic life protection. The most recent criteria available specifically for wildlife were developed in 1979 by the Canadian Government (Environment Canada, 1979). The criterion for protection of wildlife used by the Canadian Government for salt water conditions is 500 ug/L. It is unclear whether this criterion would also apply under conditions in the San Joaquin Valley or under conditions where a strong biological food chain is present as is true in most of the basins (Knight and Parker, 1988). A full review of this criterion is needed since conditions in the San Joaquin Valley are different from Canada and as shown in Figure 4, samples collected to date show that as much as 60 percent of the presently ponded acreage approaches or exceeds the 500 ug/L protection criterion.

The presence of uranium at such high concentrations might indicate the presence of high levels of the much more hazardous radium isotopes. Radium, which has geochemical properties similar to those of barium, is especially hazardous because of its easy incorporation into bone tissue, leading to malignancies(Schroeder et al., 1988). Standards or criteria for radium and its isotopes for protection of aquatic life and wildlife are not presently available. Drinking water standards are available however they are based upon radiometric activity of the sample in picocuries per liter (pCi/L) and the high salt concentration in the evaporation basins often suppresses activity readings and thus may produce an error in activity levels. A full evaluation of the presence of radium and its isotopes should be conducted.

In addition to a review of the wildlife protection criteria, a review of the drinking water standard in California is needed along with a review of the needed groundwater protection criteria under Subchapter 15 of the California Code of Regulations (CCR), Title 23, Sections 2510-2601. Limited data from interceptor drains near existing evaporation basins indicate that the uranium ion may move readily from

the basin with the water. For example, in Basin 10 the interceptor drain carries a similar concentration to that of the basin while the inflow from the tile drained area shows a lower concentration.

Uranium at low levels from naturally occurring sources is not regulated by the California Department of Health Services or the Federal Government. Title 17(Public Health), Chapter 5, Subchapter 4, Section 30180 and Section 3100(ag) and Title 22(Social Security), Division 4, Environmental Health, Chapter 30, Section 66300(b) exclude from regulation nuclear material and ores of the concentrations being found in the basins at the present time. On the Federal level, the regulations do not deal with storage or disposal of natural or unlicensed materials.

The main regulation governing uranium accumulation in evaporation basins is the designated waste definition in Subchapter 15 of the California Code of Regulations(CCR), Title 23, Sections 2510 - 2601. Section 2521(a) of Subchapter 15 refers to Title 22 for a definition of Hazardous Waste. No criteria or levels exist for uranium with regard to the hazardous waste criteria of Title 22, California Code of Regulations (CCR) Section 66699 and Section 66300 exempts radioactive wastes from the definition. The regulation of natural uranium in the evaporation basins is therefore under the designated waste provisions of Subchapter 15 where a determination is made on a site-by-site basis whether the storage and disposal poses a water quality threat.

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APPENDIX SELECTED TRACE ELEMENT WATER QUALITY DATA

APPENDIX A. Selected Trace Element Concentrations for Evaporation Basins and Basin Inlets.

SITE NAME	CELL	DATE	U	As	Mo	Se	TDS
			.....	ug/L	.....		mg/l
4 SUMNER PECK	1	06/09/87	160	3	84	855	11200
4 SUMNER PECK	1	06/08/88	160		90	772	12000
4 SUMNER PECK	1-NW INLET	06/09/87	130	4		943	
4 SUMNER PECK	1-SE INLET	06/09/87	130	2	45	460	7460
4 SUMNER PECK	1-SE INLET	06/08/88	97		40	757	8000
4 SUMNER PECK	2	06/09/87	330	4	188	1314	23400
4 SUMNER PECK	2	06/08/88	430		235	1313	33000
4 SUMNER PECK	3	06/09/87	170	3	96	866	13700
4 SUMNER PECK	3	06/08/88	260		152	685	23400
4 SUMNER PECK	3-W INLET	06/09/87	140	3	58	585	9600
4 SUMNER PECK	4	06/09/87	340	4	190	1443	25600
4 SUMNER PECK	5	06/09/87	530	5	286	1717	34600
4 SUMNER PECK	5	06/08/88	720		422	2207	48000
4 SUMNER PECK	6	06/09/87	130	5	88	467	11000
4 SUMNER PECK	6	06/08/88	200		122	794	18200
5 BRITZ-DEAV 5PTS	North	06/08/87	63	10	391	37	24300
5 BRITZ-DEAV 5PTS	North	06/08/88	63		272	79	20000
5 BRITZ-DEAV 5PTS	South	06/08/87	57	5	313	35	18300
5 BRITZ-DEAV 5PTS	South	06/08/88	61		282	74	19300
5 BRITZ-DEAV 5PTS	S-INLET	06/08/87	64	3	325	93	14500
6 STONE LAND CO.	INLET SUMP 27	06/10/87	24	4	128	0.7	9390
6 STONE LAND CO.	INLET SUMP 27	06/07/88	33		198	1.6	8900
6 STONE LAND CO.	INLET SUMP 3	06/10/87	120	8	724	6.2	29300
6 STONE LAND CO.	INLET SUMP 3	06/07/88	110		778	3.7	19000
6 STONE LAND CO.	INLET SUMP 34F	06/10/87	48	4	412	3.1	19000
6 STONE LAND CO.	INLET SUMP 34F	06/07/88	41		319	2.1	19000
6 STONE LAND CO.	INLET SUMP 36	06/10/87	41	2	192	0.3	25700
6 STONE LAND CO.	NORTH (a)	06/08/87	47	12	358	1.6	26200
6 STONE LAND CO.	NORTH (a)	06/07/88	41		320	1.0	23000
6 STONE LAND CO.	NORTH (b)	06/08/87	47	13	370	2.1	27200
6 STONE LAND CO.	NORTH (b)	06/07/88	41		334	1.1	22000
6 STONE LAND CO.	SE (a)	06/08/87	170	40	902	2.1	116000
6 STONE LAND CO.	SE (a)	06/07/88	220		962	2.0	160000
6 STONE LAND CO.	SE (b)	06/08/87	180	41	965	0.7	120000
6 STONE LAND CO.	SE (b)	06/07/88	220		952	2.2	150000
6 STONE LAND CO.	SW INLET	06/10/87	52	5	636	4.3	34100
6 STONE LAND CO.	SW INLET	06/07/88	110		785	4.3	21000
6 STONE LAND CO.	SW (a)	06/08/87	150	22	1002	2.9	83200
6 STONE LAND CO.	SW (a)	06/07/88	150		735	4.8	74000
6 STONE LAND CO.	SW (b)	06/08/87	140	20	985	2.6	78600
6 STONE LAND CO.	SW (b)	06/07/88	160		725	4.7	76000
7 CARLTON DUTY	AG INLET	06/08/87	100	5	245	17	51350
7 CARLTON DUTY	BASIN	06/08/87	320	200	866	15	171000
7 CARLTON DUTY	BASIN	06/08/88	530		459	13	210000
7 CARLTON DUTY	INCPTR INLET	06/08/87	110	50	504	15	47400
7 CARLTON DUTY	INCPTR INLET	06/08/88	120		1285	13	48000

APPENDIX A. Selected Trace Element Concentrations (cont.)

SITE NAME	CELL	DATE	U	As	Mo	Se	TDS
			ug/L				mg/l
8 WESTLAKE-NORTH	1-N	06/08/87	180	20	546	1.6	26700
8 WESTLAKE-NORTH	1-N	06/08/87	180	23	572	0.4	26700
8 WESTLAKE-NORTH	1-NE	06/08/88	450		1408	1.5	91000
8 WESTLAKE-NORTH	1-NW INLET	06/08/87	94	12	408	2.1	10500
8 WESTLAKE-NORTH	1-S	06/08/88	480		1840	1.7	110000
8 WESTLAKE-NORTH	1-SW INLET	06/08/87	170	14	338	0.6	22700
8 WESTLAKE-NORTH	1-SW INLET	06/08/88	150		272	1.1	23000
8 WESTLAKE-NORTH	2-INLET	06/08/87	170	11	296	0.5	22100
8 WESTLAKE-NORTH	2-INLET	06/08/88	160		261	1.0	24000
8 WESTLAKE-NORTH	2-NE	06/08/87	200	21	586	1.9	38400
8 WESTLAKE-NORTH	2-NE (d)	06/08/88	210		447	1.1	43000
8 WESTLAKE-NORTH	2-SE	06/08/87	200	26	584	2.1	38300
8 WESTLAKE-NORTH	2-SE (c)	06/08/88	210		447	1.2	43000
8 WESTLAKE-NORTH	2-SW	06/08/87	190	24	570	0.7	38200
8 WESTLAKE-NORTH	2-SW (b)	06/08/88	210		442	1.3	43000
9 MEYERS RANCH	A	06/08/87	82	13	407	0.3	17800
9 MEYERS RANCH	A	06/07/88	54		272	0.5	12000
9 MEYERS RANCH	B	06/08/87	30	8	698	0.2	25900
9 MEYERS RANCH	B	06/07/88	43		349	0.3	13000
9 MEYERS RANCH	C	06/07/88	43		432	0.3	16000
9 MEYERS RANCH	INLET	06/08/87	82	13	228	1.2	6760
9 MEYERS RANCH	INLET	06/07/88	83		182	1.0	7000
10 BARBIZON FARMS	EAST	06/08/87	200	26	504	0.8	16000
10 BARBIZON FARMS	EAST	06/07/88	220		484	1.5	17000
10 BARBIZON FARMS	E-INLET	06/10/87	140	41	224	0.6	7130
10 BARBIZON FARMS	E-INLET	06/07/88	210		300	1.4	9200
10 BARBIZON FARMS	MIDDLE	06/08/87	240	32	620	0.3	19600
10 BARBIZON FARMS	MIDDLE	06/07/88	260		872	0.5	31000
10 BARBIZON FARMS	WEST	06/08/87	260	33	752	1.3	22900
10 BARBIZON FARMS	WEST	06/07/88	260		762	0.6	25000
10 BARBIZON FARMS	W-INLET	06/10/87	220	49	533	0.9	13900
10 BARBIZON FARMS	W-INLET	06/07/88	280		664	1.3	16000
11 TLDD, NORTH	1	06/08/87	73	160	174	1.8	4045
11 TLDD, NORTH	1	06/07/88	63		173	2.0	3800
11 TLDD, NORTH	2A	06/08/87	75	230	238	1.8	6550
11 TLDD, NORTH	2A	06/07/88	83		262	1.7	6200
11 TLDD, NORTH	2B	06/08/87	67	180	164	1.9	4295
11 TLDD, NORTH	2B	06/07/88	61		176	1.9	3850
11 TLDD, NORTH	3A	06/08/87	72	200	227	1.7	6125
11 TLDD, NORTH	3A	06/07/88	66		189	2.1	4800
11 TLDD, NORTH	3B	06/08/87	68	190	184	2.1	5150
11 TLDD, NORTH	3B	06/07/88	60		182	1.7	4000
11 TLDD, NORTH	4	06/08/87	81	200	256	2.5	6915
11 TLDD, NORTH	4	06/07/88	79		242	2.0	6300
11 TLDD, NORTH	5A	06/08/87	92	240	258	2.1	7125
11 TLDD, NORTH	5A	06/07/88	73		288	1.7	7400
11 TLDD, NORTH	5B	06/08/87	130	290	420	1.9	10290
11 TLDD, NORTH	5B	06/07/88	78		293	1.7	8300

APPENDIX A. Selected Trace Element Concentrations (cont.)

SITE NAME	CELL	DATE	U	As	Mo	Se	TDS
			ug/L				mg/l
11 TLDD, NORTH	6	06/08/87	130	280	353	1.9	8750
11 TLDD, NORTH	6	06/07/88	110		427	1.9	9900
11 TLDD, NORTH	7	06/08/87	200	360	504	1.1	14220
11 TLDD, NORTH	7	06/07/88	200		582	1.0	18000
11 TLDD, NORTH	INLET	06/08/87	70	170	169	1.6	3650
11 TLDD, NORTH	INLET	06/07/88	79		209	2.6	4800
12 WESTLAKE #3	1	06/08/87	100	10	498	5.3	35850
12 WESTLAKE #3	1	06/08/88	130		429	8.6	20000
12 WESTLAKE #3	2	06/08/87	100	52	348	4.1	21500
12 WESTLAKE #3	2	06/08/88	130		402	12	26000
12 WESTLAKE #3	3	06/08/87	100	34	313	4.2	16700
12 WESTLAKE #3	3	06/08/88	130		422	16	22000
12 WESTLAKE #3	3-INLET	06/08/87	140	62	306	6.2	18825
12 WESTLAKE #3	4	06/08/87	160	25	642	7.2	62100
12 WESTLAKE #3	4	06/08/88	290		678	13	98000
12 WESTLAKE #3	5	06/08/87	94	28	429	3.1	29400
12 WESTLAKE #3	5	06/08/88	160		502	5.4	60000
12 WESTLAKE #3	6	06/08/87	93	18	489	4.1	20800
12 WESTLAKE #3	6	06/08/88	130		570	5.4	30000
14 PRYSE FARMS	1	06/10/87	740	630	2980	16	50900
14 PRYSE FARMS	1 EAST	06/08/88	580		2740	11	48000
14 PRYSE FARMS	1 WEST	06/08/88	570		2770	11	53000
14 PRYSE FARMS	2	06/10/87	1500	1200	6380	14	185000
14 PRYSE FARMS	2	06/08/88	1100		4325	9.4	100000
14 PRYSE FARMS	INLET	06/10/87	540	330	1735	13	25700
14 PRYSE FARMS	INLET	06/08/88	510		1530	9.6	25000
15 BOWMAN FARMS	A	06/09/87	470	66	3150	19	41000
15 BOWMAN FARMS	A	06/08/88	600		4280	13	52000
15 BOWMAN FARMS	B	06/09/87	790	80	5138	24	68000
15 BOWMAN FARMS	B	06/08/88	400		6465	33	80000
15 BOWMAN FARMS	NE-INLET	06/09/87	930	130	1670	21	15200
15 BOWMAN FARMS	NW-INLET	06/09/87	630	240	3088	17	50500
15 BOWMAN FARMS	NW-INLET	06/08/88	570		2835	13	49000
16 MORRIS FARMS	CELL	06/09/87	1200	100	5250	44	53800
16 MORRIS FARMS	CELL	06/08/88	460		3565	23	42000
16 MORRIS FARMS	INLET	06/09/87	1200	240	2875	76	19500
16 MORRIS FARMS	INLET	06/08/88	1100		2145	54	17000
17 MARTIN FARMS	CELL	06/09/87	1900	240	10125	51	78400
17 MARTIN FARMS	CELL	06/08/88	910		4350	37	32000
17 MARTIN FARMS	INLET	06/08/88	1200		2600	60	18000
19 4-J CORP	CELL	06/10/87	2500	2500	5595	53	65800
19 4-J CORP	CELL	06/08/88	2400		4080	50	58000
19 4-J CORP	N-INLET	06/10/87	700	900	1555	36	19200
21 TLDD HACIENDA	A1	06/08/87	440	110	912	21	8320
21 TLDD HACIENDA	A1	06/07/88	370		920	25	8400
21 TLDD HACIENDA	A1-INLET	06/08/87	440	130	755	19	6780
21 TLDD HACIENDA	A2 (a)	06/08/87	390	100	1332	19	12600
21 TLDD HACIENDA	A2 (a)	06/07/88	470		1080	22	11000

APPENDIX A. Selected Trace Element Concentrations (cont.)

SITE NAME	CELL	DATE	U	As	Mo	Se	TDS
			ug/L				mg/l
21 TLDD HACIENDA	A2 (c)	06/08/87	430	110	1615	16	15300
21 TLDD HACIENDA	A2 (c)	06/07/88	400		1220	21	13000
21 TLDD HACIENDA	A3	06/08/87	800	220	2185	14	29200
21 TLDD HACIENDA	A3	06/07/88	810		2065	13	27000
21 TLDD HACIENDA	A4	06/08/87	2200	390	5000	14	107000
21 TLDD HACIENDA	A4	06/07/88	2600		5860	12	130000
21 TLDD HACIENDA	C1	06/09/87	410	100	1125	21	10400
21 TLDD HACIENDA	C1	06/07/88	460		1090	21	11000
21 TLDD HACIENDA	C2	06/09/87	620	200	1478	22	21000
21 TLDD HACIENDA	C2	06/07/88	750		1640	19	23000
21 TLDD HACIENDA	C3	06/09/87	1000	300	2168	20	42200
21 TLDD HACIENDA	C3	06/07/88	950		2070	18	36000
21 TLDD HACIENDA	C4	06/07/88	1800		3180	15	85000
21 TLDD HACIENDA	C4 NE COR	06/09/87	2300	480	4340	18	112000
21 TLDD HACIENDA	C4 SW COR	06/09/87	2600	490	4845	17	129000
21 TLDD HACIENDA	MARSH N CELL	06/09/87	590	170	962	19	10100
21 TLDD HACIENDA	MARSH N CELL	06/07/88	1800		3340	36	55000
21 TLDD HACIENDA	MARSH S CELL	06/09/87	780	180	1142	20	11900
21 TLDD HACIENDA	MARSH S CELL	06/07/88	2500		4535	41	77000
22 TLDD, SOUTH	1 N SIDE	06/08/88	390		1170	17	15000
22 TLDD, SOUTH	1 SE SIDE	06/09/87	510	120	1320	23	13600
22 TLDD, SOUTH	1 SW SIDE	06/09/87	530	140	1310	22	13900
22 TLDD, SOUTH	1 SW SIDE	06/08/88	370		1045	16	17200
22 TLDD, SOUTH	10	06/09/87	2600	360	5925	14	104000
22 TLDD, SOUTH	10	06/08/88	3100		7600	9.8	140000
22 TLDD, SOUTH	2	06/09/87	440	120	1358	18	15400
22 TLDD, SOUTH	2	06/08/88	370		1270	15	18000
22 TLDD, SOUTH	3	06/09/87	540	160	1772	16	20400
22 TLDD, SOUTH	3	06/08/88	460		1545	15	21000
22 TLDD, SOUTH	4	06/09/87	1000	280	2670	15	42900
22 TLDD, SOUTH	4	06/08/88	600		1900	15	29000
22 TLDD, SOUTH	5	06/09/87	1100	290	2650	15	52200
22 TLDD, SOUTH	5	06/08/88	910		2710	17	48000
22 TLDD, SOUTH	6	06/09/87	480	140	1468	14	17000
22 TLDD, SOUTH	6	06/08/88	1300		3120	15	66000
22 TLDD, SOUTH	7	06/09/87	580				17900
22 TLDD, SOUTH	7	06/08/88	910		2210	10	38000
22 TLDD, SOUTH	8	06/09/87	790	200	2058	9.8	27900
22 TLDD, SOUTH	8	06/08/88	860		2250	8.7	33000
22 TLDD, SOUTH	9	06/09/87	1200	290	2900	11	49850
22 TLDD, SOUTH	9	06/08/88	1400		3350	9.7	55000
22 TLDD, SOUTH	INLET	06/09/87	510	130	970	19	10300
22 TLDD, SOUTH	INLET	06/07/88	460		1065	30	9000
22 TLDD, SOUTH	PERIM DRAIN	06/09/87	520	90	2625	4.8	33300
22 TLDD, SOUTH	PERIM DRAIN	06/08/88	400		2100	3.4	29000
22 TLDD, SOUTH	SALT BASIN	06/09/87	550				21500
22 TLDD, SOUTH	SALT BASIN	06/08/88	630		1670	20	28000
23 LOST HILLS WD	1 (a)	06/09/87	240	10	1600	199	35900

APPENDIX A. Selected Trace Element Concentrations (cont.)

SITE NAME	CELL	DATE	U	As	Mo	Se	TDS
			ug/L				mg/l
23 LOST HILLS WD	1 (a)	06/08/88	180		1565	176	31000
23 LOST HILLS WD	1 (c)	06/09/87	230	10	1665	196	35500
23 LOST HILLS WD	1 (c)	06/08/88	200		1355	177	31000
23 LOST HILLS WD	1-INLET	06/09/87	130	3	429	140	9560
23 LOST HILLS WD	1-INLET	06/08/88	120		796	142	14000
23 LOST HILLS WD	3A NORTH	06/09/87	430	18	2720	345	85800
23 LOST HILLS WD	3A NORTH	06/07/88	480		3480	589	100000
23 LOST HILLS WD	3A SOUTH	06/09/87	430	16	2710	307	84300
23 LOST HILLS WD	3A SOUTH	06/07/88	480		3440	603	110000
23 LOST HILLS WD	3A-INLET	06/09/87	170	7	1665	645	31400
23 LOST HILLS WD	3B NORTH	06/09/87	350	11	2045	145	57700
23 LOST HILLS WD	3B NORTH	06/08/88	340		2020	156	68000
23 LOST HILLS WD	3B SOUTH	06/09/87	350	14	1800	150	56000
23 LOST HILLS WD	3B SOUTH	06/07/88	310		1605	135	56000
23 LOST HILLS WD	3C	06/09/87	260	10	1865	199	38300
23 LOST HILLS WD	3C	06/07/88	240		1450	126	43000
23 LOST HILLS WD	4-NE	06/07/88	340		2270	163	69000
23 LOST HILLS WD	4-NW	06/07/88	350		2150	161	71000
23 LOST HILLS WD	Borrow Pit	06/08/88	200		1170	102	39000
23 LOST HILLS WD	Borrow Pit	06/09/87	59	8	296	58	11800
24 CARMEL RANCH	1	06/10/87	1000	1500	4348	2.4	37100
24 CARMEL RANCH	1	06/07/88	1100		5430	2.1	51000
24 CARMEL RANCH	1-INLET	06/10/87	570	800	2530	2.8	17000
24 CARMEL RANCH	2	06/10/87	3300	2800	9745	3.2	112000
24 CARMEL RANCH	2	06/07/88	10000		22850	4.6	200000
24 CARMEL RANCH	3	06/10/87	1000	620	3020	3.7	24200
24 CARMEL RANCH	3	06/07/88			9550	3.9	24000
24 CARMEL RANCH	4	06/10/87	600	360	1880	3.8	13600
24 CARMEL RANCH	4	06/07/88	770		2425	4.1	17000
24 CARMEL RANCH	5	06/10/87	11000	13000	39900	5.4	388000
24 CARMEL RANCH	5	06/07/88	2500		10450	3.1	130000
25 LOST HILLS RANCH	1	06/10/87	240	960	2940	3.1	15300
25 LOST HILLS RANCH	1	06/07/88	200		2815	2.8	13000
25 LOST HILLS RANCH	1-INLET	06/10/87	260	860	2640	3.2	14600
25 LOST HILLS RANCH	1-INLET	06/07/88	200		2760	2.4	14000
25 LOST HILLS RANCH	2	06/10/87	260		5015	2.6	23800
25 LOST HILLS RANCH	2	06/07/88	360		4805	3.8	21000
25 LOST HILLS RANCH	3	06/10/87	470	820	6980	3.3	40400
26 SAM ANDREWS & SONS	1	06/11/87	980	13	8705	802	128000
26 SAM ANDREWS & SONS	1	06/07/88	340		1825	239	25000
26 SAM ANDREWS & SONS	2A	06/11/87	490	4	2580	366	42700
26 SAM ANDREWS & SONS	2A	06/07/88	430		2220	286	32000
26 SAM ANDREWS & SONS	2B	06/11/87	410	5	2090	303	33400
26 SAM ANDREWS & SONS	2B	06/07/88	380		2005	257	27000
26 SAM ANDREWS & SONS	3A	06/11/87	540	13	2670	359	42600
26 SAM ANDREWS & SONS	3A	06/07/88	510		2560	339	35000
26 SAM ANDREWS & SONS	3B	06/11/87	650	7	3480	455	56500
26 SAM ANDREWS & SONS	3B	06/07/88	460		2380	307	36000

APPENDIX A. Selected Trace Element Concentrations (cont.)

SITE NAME	CELL	DATE	U	As	Mo	Se	TDS
			ug/L				mg/l
26 SAM ANDREWS & SONS	4A	06/11/87	870	9	5088	606	79100
26 SAM ANDREWS & SONS	4A	06/07/88	780		3960	456	61000
26 SAM ANDREWS & SONS	4B	06/11/87	800	8	4310	505	67000
26 SAM ANDREWS & SONS	4B	06/07/88	2200		12300	1193	160000
26 SAM ANDREWS & SONS	4B-INLET	06/11/87	740	13	4360	492	64600